TECHNICAL MEMORANDUM

SUBJECT: Methodology Used to Determine the Spatial Extent of Fresh Water Impact in Barataria Bay and Black/Bay Breton Sound Basins in 2010

DATE: September 4, 2015

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INTRODUCTION

Following the Deepwater Horizon oil spill (DWH spill) in April 2010, the state of Louisiana opened two water control structures in the Mississippi River in attempt to minimize the amount of oil reaching the shore (Rose et al. 2014). These structures directed large amounts of river water into Barataria Bay (through the Davis Pond structure) and Black Bay/Breton Sound (through the Caernarvon structure). Figure 1 depicts the locations of the river water diversion structures and their respective basins of influence. The Caernarvon diversion was opened three days after the explosion (April 23, 2010) and remained open through the first two weeks of August with flow at or near maximum capacity (approximately 8,000 cubic feet per second (cfs)). The Davis Pond diversion remained open from May 8 through September 10, 2010, with flow ranging from 7,000 to 10,000 cfs. The 2010 opening of these structures was atypical in that they remained open longer than usual and maintained high flow rates during the spring and summer seasons when they are usually closed. As shown by Figures 2 and 3, the average river water flow through Caernarvon and Davis Pond diversions during the spring and summer months of April – September were elevated during 2010 compared to flow rates over the same time period in preceding and following years. Substantial river water releases can lead to salinity drops that may have impacts on marine life. The purpose of this technical memorandum is to describe the processes used to determine the spatial extent of areas within Barataria Bay and Black Bay/Breton Sound basins in Louisiana which experienced lower salinities in 2010 than those of prior (baseline) years (2006-2009) for a prolonged period of time (>30 days). The period 2006-2009 was chosen to represent baseline conditions because it was after Hurricane Katrina (2005) and is most likely to represent conditions that would have occurred in the absence of the *Deepwater Horizon* spill. For all analyses herein, the common time period of April 27th through September 15th was used as the temporal range of investigation as this is when the river water from the diversions would have reached the oyster study areas (Powers *et al.*, 2015).

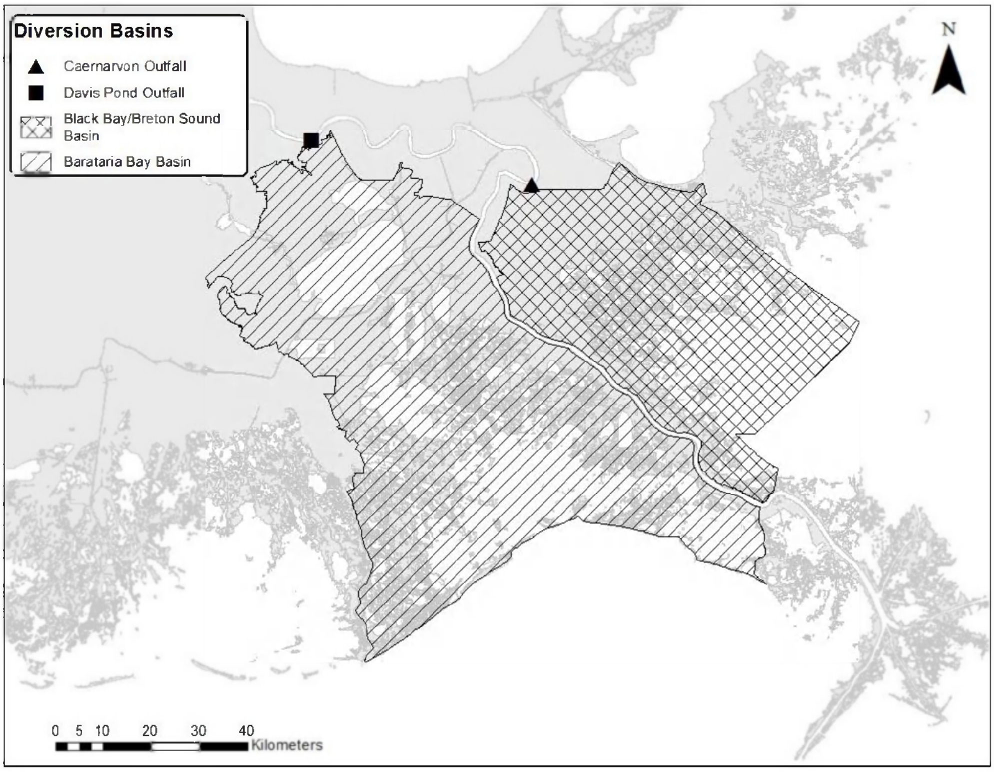

Figure 1- Mississippi River diversion outfall locations and their respective basins of influence.

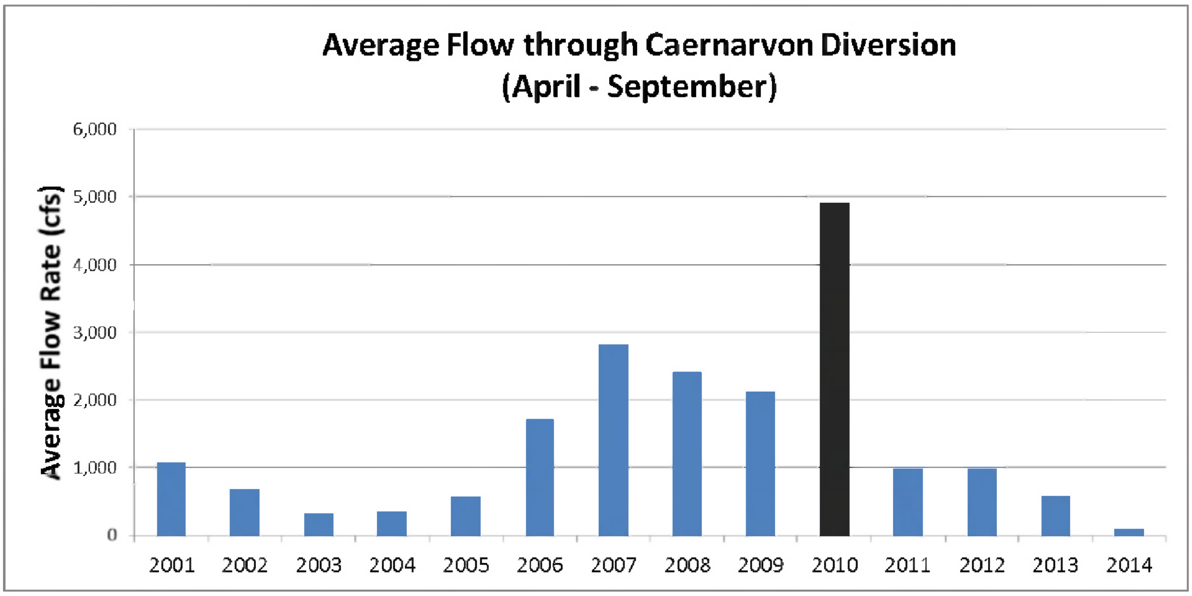

Figure 2 Average flow rate through the Caernarvon diversion during the months of April – September for each year

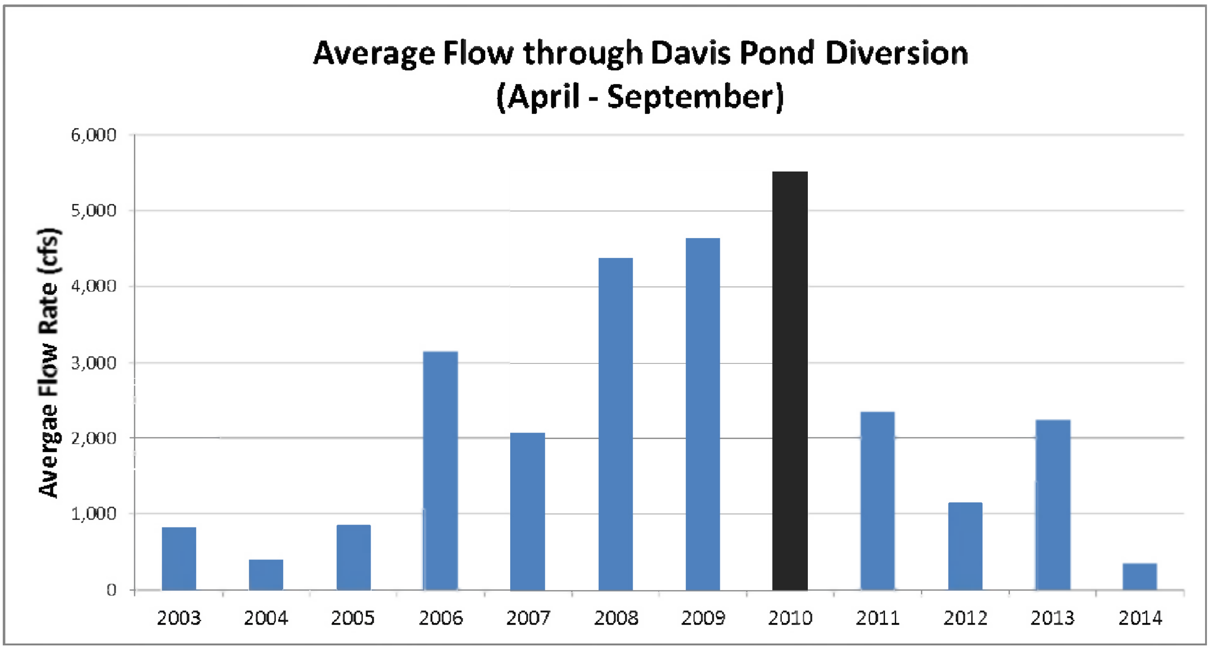

Figure 3 Average flow rate through the Davis Pond diversion during the months of April – September for each year

Modeled Salinity Data

Daily average salinities for 2006 through 2012 were estimated using a spatio-temporal kriging model fit to an extensive dataset of water quality observations in Barataria Bay and Black Bay/Breton Sound (McDonald *et al.*, 2015). The model incorporated both continuous (hourly or daily) monitor data and discrete measurements of water quality to estimate daily salinities for each cell in a dense 200-meter by 200-meter grid that overlaid the respective basins. The model relied upon salinity data collected by the Louisiana Department of Wildlife and Fisheries (LDWF), the Louisiana Office of Coastal Protection and Restoration (LOCPR), the Louisiana Department of Health and Hospitals (LDHH), the Louisiana Department of Environmental Quality (LDEQ), the United States Geological Survey (USGS), and measurements recorded during DWH natural resource damage assessment (NRDA) oyster sampling. The locations of water quality/salinity monitoring stations are shown in Figure 4.

The results of the model were subjected to two hold-out cross-validation procedures which yielded statistically significant correlations between measured and predicted values across multiple years and basins. Therefore, the model results can be reliably used in estimating salinity conditions at locations and days where physical water quality measurements were not collected. A detailed description of the model and its validation results can be found in McDonald et al. (2015).

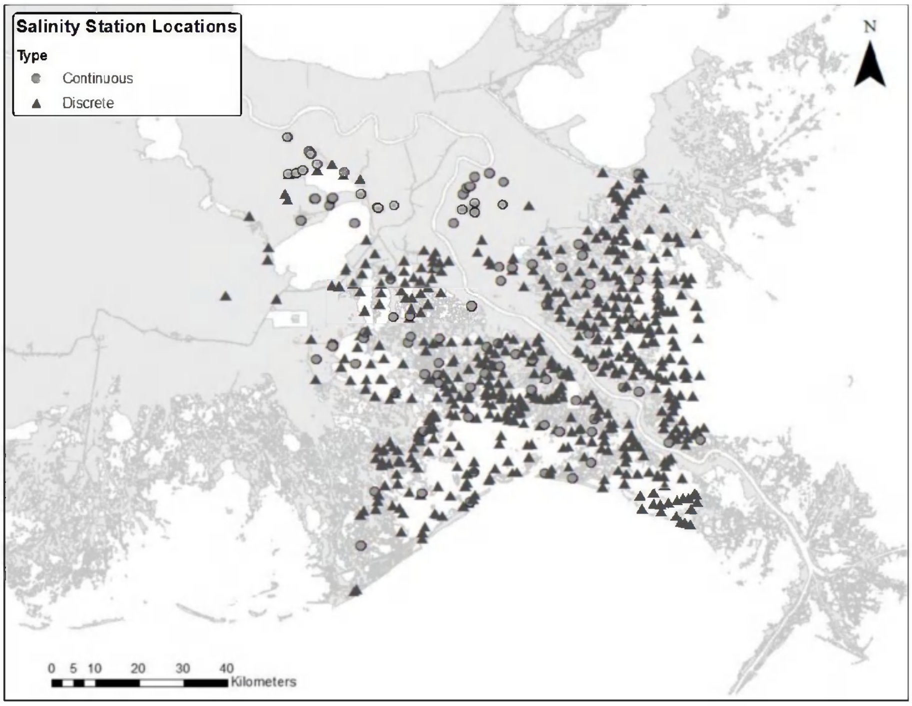

Figure 4 Location of salinity stations used in spatio-temporal kriging model

METHODOLOGY

5ppt Fresh Water Polygon

For each 200 m^2 grid cell in the salinity model, the maximum number of consecutive days[1] of low salinity (below 5 parts per thousand (ppt)) during the April 27th-September 15th time period was calculated for each year between 2006 and 2010. For each grid cell, the maximum number of consecutive days was averaged for years 2006-2009 as a representation of the "historical baseline condition" for that location. Each grid cell that experienced more than 30 consecutive days of low salinity above that experienced in the historical baseline was considered affected by fresh water in 2010. A polygon of all affected grid cells was created which represents the area with a significant increase in prolonged low salinity exposure in 2010 relative to baseline conditions. The threshold of 30 days[2] was selected to maximize the difference between average salinities inside and outside the resulting fresh water polygon in 2010 (Figure 5), thereby representing the greatest low salinity impact.

[1] Brief periods when average daily salinities rose above 5 ppt for less than 3 days were ignored in the computation of consecutive days.
[2] In Barataria Bay, this maximum occurs at 30 additional consecutive days whereas in Black Bay/Breton Sound the maximum occurs slightly earlier. However, to be conservative, we decided to use the same 30 days threshold for both areas.

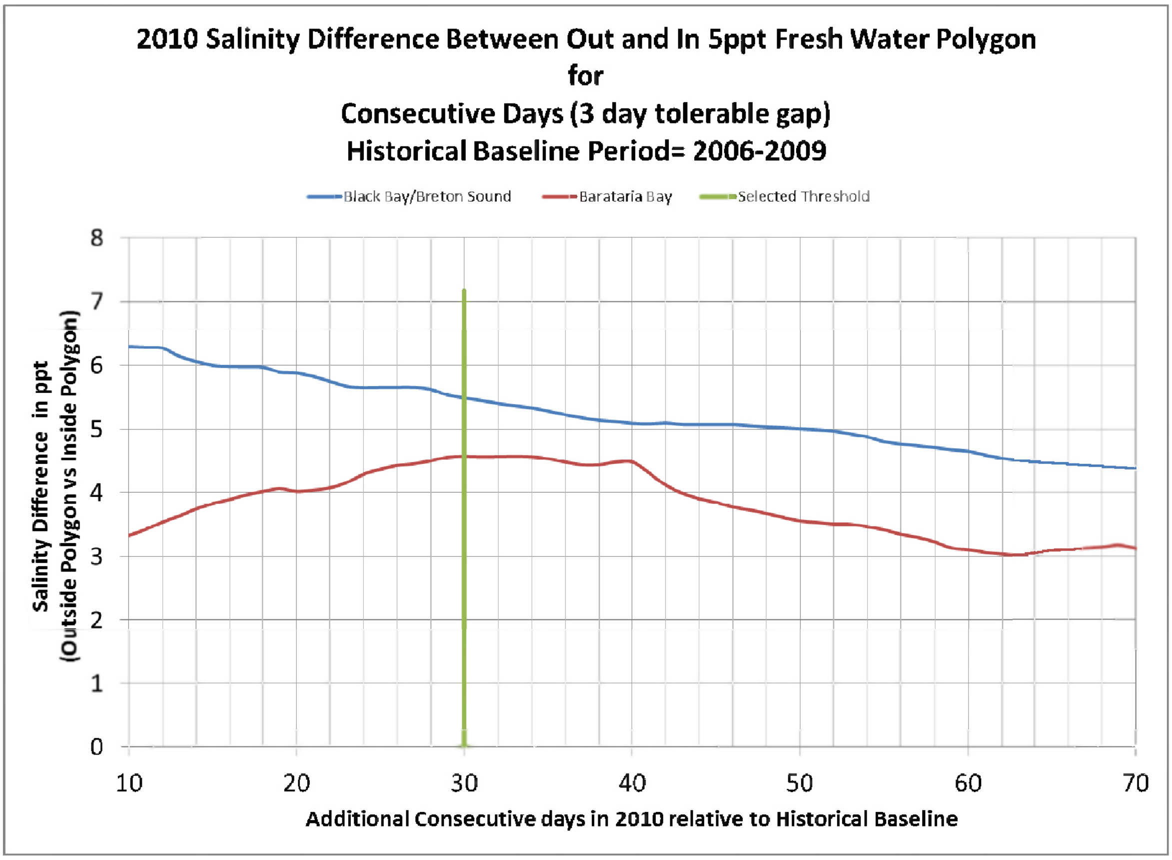

Figure 5 Determination of the additional fresh water day threshold by maximizing In vs Out salinities

8ppt Fresh Water Polygon

Exposure to salinities as low as 8ppt can affect spawning and growth rates of oysters (Davis H.C.,1958). To help determine those areas that may have experienced these deleterious effects, it was important to distinguish areas that were exposed to lower salinities for prolonged periods during 2010, irrespective of historical conditions. For this purpose, all grid cells from the spatial-temporal salinity model that experienced a total of 30 days[3] or more below 8 ppt (regardless if those days occurred consecutively or not) between April 27th and September 15th of 2010 were considered to be influenced by fresh water. All fresh-water-influenced cells were aggregated to create an 8ppt fresh water influence polygon. This process was repeated for 2009 and 2011 to determine conditions before and after the atypical diversion openings in 2010.

[3] Although a number of thresholds for the total number of days were explored, 30 days was used in order to maintain consistency with the parameters used in the 5ppt polygon.

RESULTS

5ppt Fresh Water Polygon Results

All affected grids which experienced more than 30 additional consecutive days below 5ppt in 2010 compared to historical baseline conditions were consolidated into comprehensive freshwater polygons per basin, as shown in Figure 6. In this figure, all land areas were removed from the resulting polygons. Figure 7 displays the outline extent of these polygons along with shoreline oiling exposure as determined by Nixon *et al.* (2015).

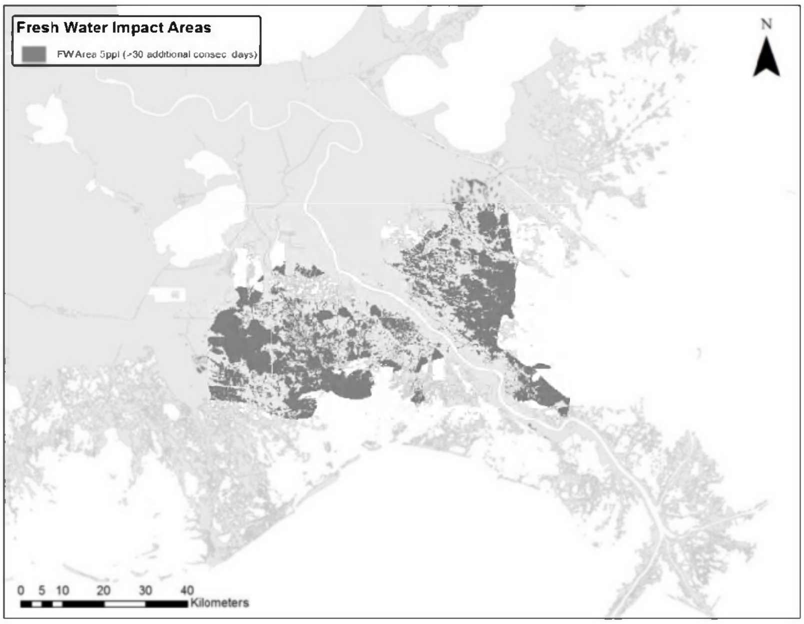

Figure 6 Locations in Barataria Bay and Black Bay/Breton Sound basins with more than 30 consecutive days with salinity below 5 parts per thousand in 2010 compared to the number of consecutive days below 5 ppt during historical baseline years. These areas represent the influence of the river water releases in response to the *Deepwater Horizon* spill.

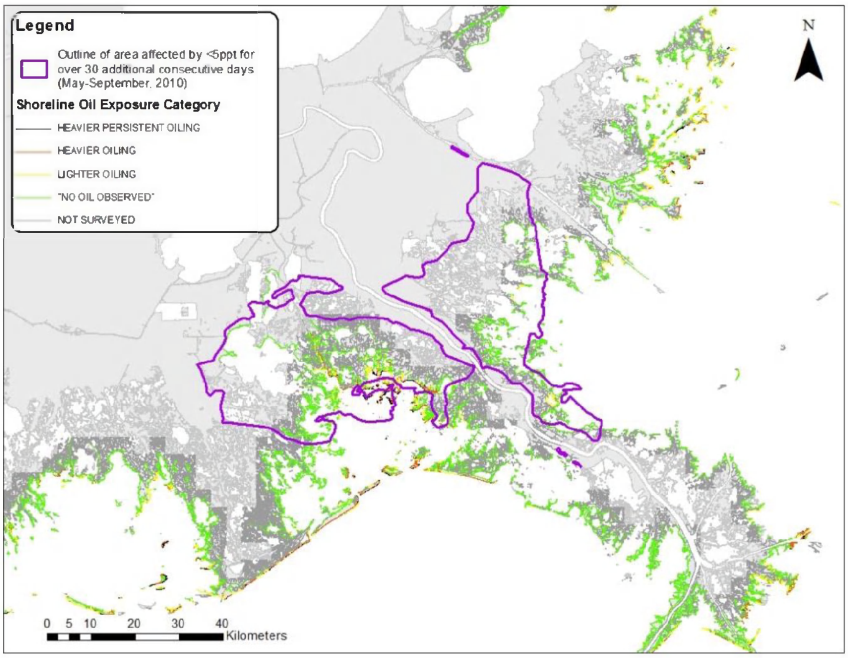

Figure 7 The approximate outline of areas in Barataria Bay and Black Bay/Breton Sound basins with more than 30 consecutive days with salinity 5 parts per thousand in 2010 compared to the number of consecutive days below 5 ppt during historical baseline years. In the background, shoreline oiling exposures are displayed consistent with the findings of Nixon *et al.* (2015).

Extended periods of exposure to low salinity not typically experienced in an area can have an important impact on sensitive marine animals such as oysters which are not mobile or able to evade the fresh water and whose survival declines dramatically the longer they are exposed to fresh water (Powers *et al.*, 2015). The resulting 5ppt fresh water polygon represents the area of fresh water impact due to the influence of the river water releases in response to the *Deepwater Horizon* spill and is useful in determining areas where the health and survival of sensitive marine animals, if present, may have been compromised. The fresh water impact area covered 483 km^2 in Barataria Bay and 362 km^2 in Black Bay/Breton Sound, respectively. Consistent with oyster cover maps presented in Roman *et al.* (2015), the freshwater impact area covers 199 and 280 km^2 (a total of 479 km^2) of oyster habitats in Barataria Bay and Black Bay/Breton Sound, respectively.

The above results indicate major changes in the hydrographic regime of both the Barataria and the Black Bay/Breton Sound basins during the summer of 2010. On average, compared to historical values, locations in the study area experienced 20.3 additional consecutive days of low salinity (<5ppt) in 2010, with a maximum of 138 days.

During the spring and summer months in 2011, the Caernarvon and Davis Pond diversions were opened in a manner consistent with typical historical years (Figure 2 and Figure 3). Locations in Barataria Bay and Black Bay/Breton Sound basins with more than 30 consecutive days below 5 parts per thousand in 2011were aggregated to create a fresh water impact polygon for that year. Figure 8 indicates that there was very little area experiencing unusually low salinities relative to historic averages in either Barataria Bay or Black Bay/Breton Sound basins in 2011. This indicates the areas delineated by the 5ppt polygon in 2010 represent the influence of the atypical opening of river water diversions in response to the Deepwater Horizon spill.

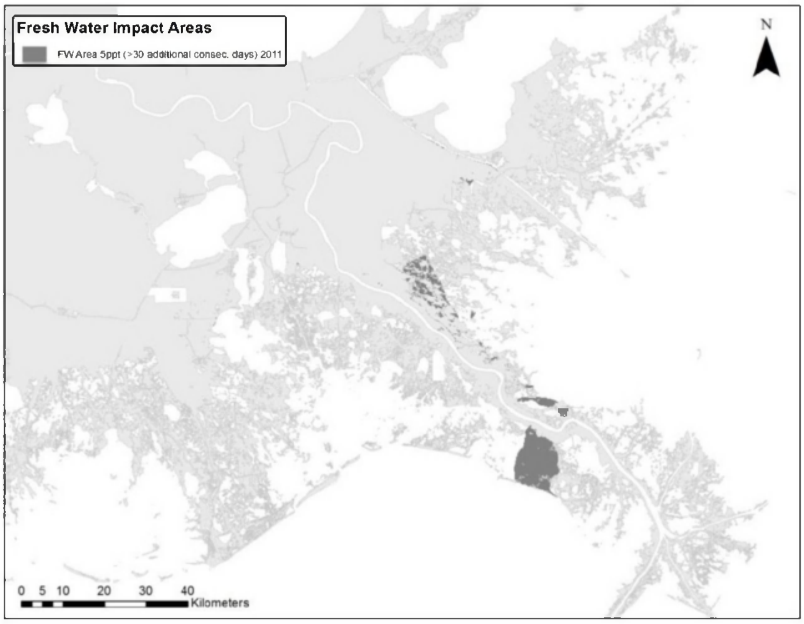

Figure 8 Locations in Barataria Bay and Black Bay/Breton Sound basins with more than 30 consecutive days below salinity threshold of less than 5 parts per thousand in 2011 compared to the number of consecutive days below 5 ppt during historical baseline years. These areas indicate that when the diversions are opened under normal conditions, the basins as a whole do not experience substantial areas with salinities below their historical baseline conditions.

8ppt Fresh Water Polygon Results

All grid cells which experienced more than 30 total days below 8ppt were consolidated into comprehensive freshwater influence polygons for 2009, 2010, and 2011, as shown in Figure 9, 10, and 11, respectively.

The spatial extent of salinities lower than 8ppt for greater than 30 total days were very similar for 2009 and 2011, but showed a marked increase in 2010 during the time in which the freshwater diversions were open (Figure 12). These results further highlight the increased fresh water influence caused by the atypical opening of the diversions in 2010.

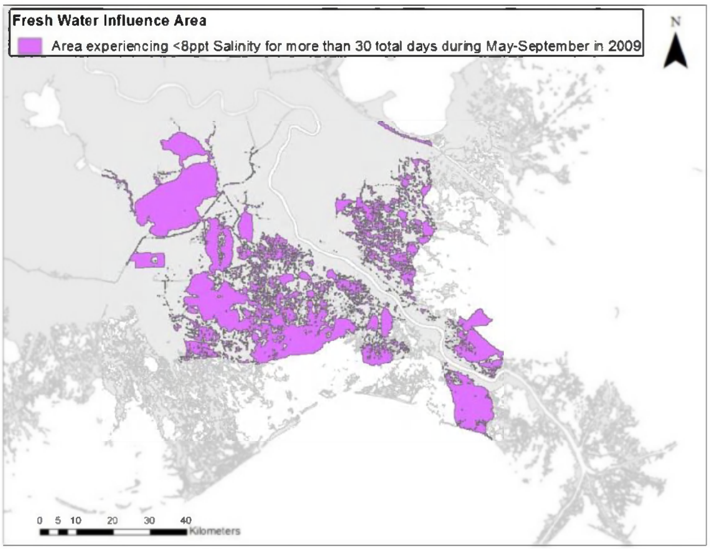

Figure 9 Freshwater polygon in 2009 based on salinities below 8ppt for more than 30 total days.

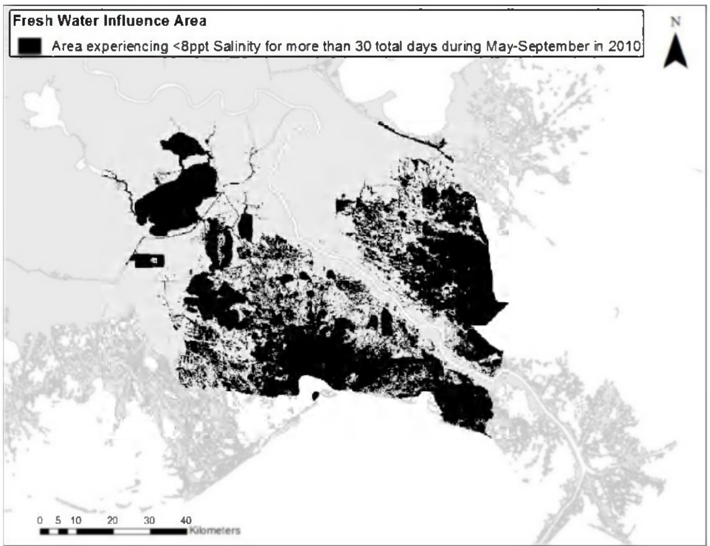

Figure 10 Freshwater polygon in 2010 based on salinities below 8ppt for more than 30 total days.

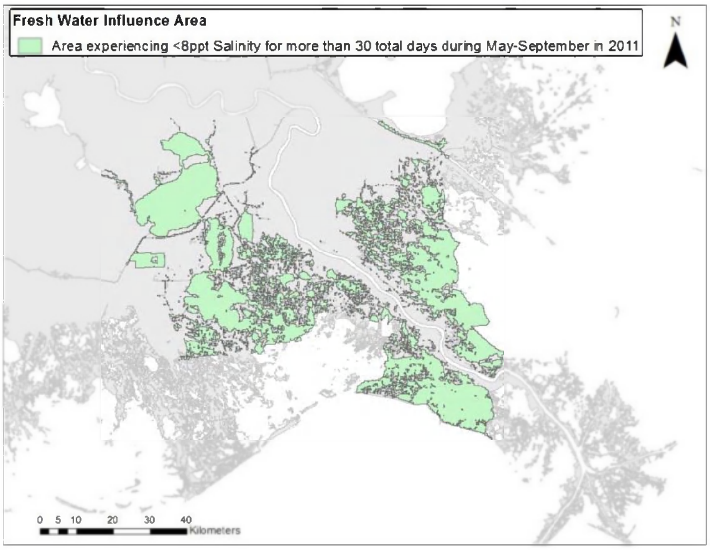

Figure 11 Freshwater polygon in 2011 based on salinities below 8ppt for more than 30 total days.

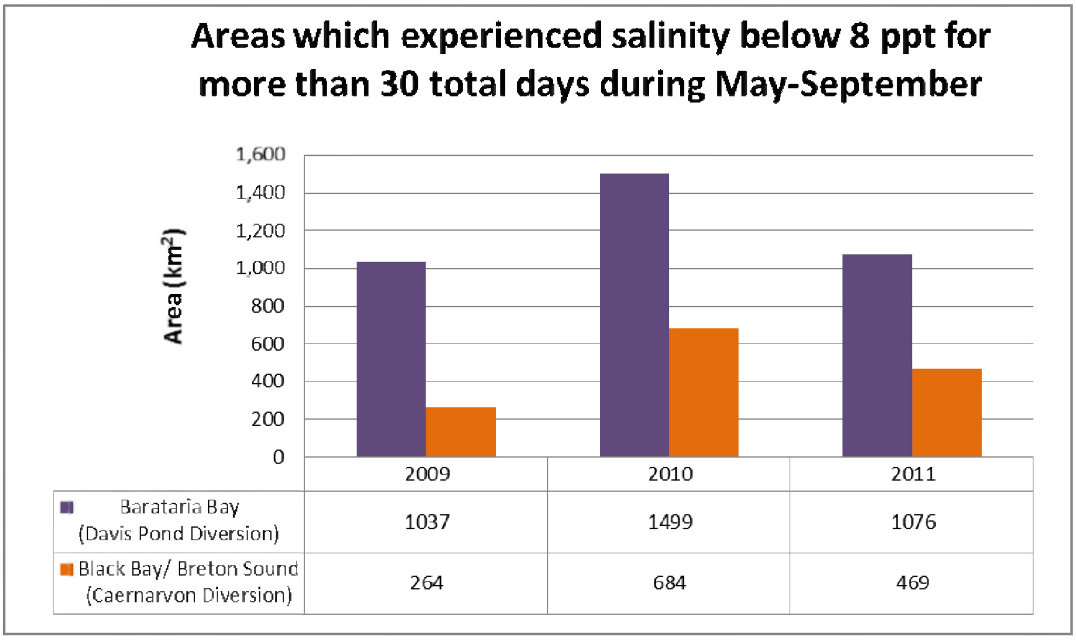

Figure 12 Areas in Barataria Bay and Black Bay/Breton Sound which experienced salinities below 8ppt for more than 30 total days during spring and summer months of 2009, 2010, and 2011. The areas influenced by low salinities in 2010 are larger than 2009 or 2011. This increase in the 2010 fresh water influence area was a result of the atypical opening of the diversions in 2010.

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